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ABSTRACT

This project developed a mobile spectroscopy laboratory, a truck equipped with scientific instruments which can be moved from school to school to provide hands-on experience with instruments normally too expensive for a small school to purchase. A summer conference trained the on-campus participant faculty in the use of the truck-laboratory as well as in trouble-shooting techniques with the instruments to be used. Two instruments were permanently mounted due to temperature and vacuum requirements. Four other instruments were fitted into detachable drawers so they could be used inside the permanent laboratories of the participating schools or moved independently of the mobile laboratory. To encourage cooperation among participating schools, each was free to alter, maintain, or adjust its curriculum. A schedule for movement of the vehicle was made each year by the participants, which also served to foster an increased cooperation among participants. Evaluation conferences were held at the end of the summer after the first two years and an outside panel, listening to accounts of experiences, judged it a success and recommended it for duplication. Newspaper and professional articles, television news coverage, and the presence of the van at national meetings helped to publicize the project. (Author/JN)

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Project Number: HES 75-14376

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Date Awarded: June 1, 1975

Duration: 36 months
(extended 1 year by request)

Project Title: Development of a Mobile Spectroscopy Laboratory

Project Director: T.D. Roberts

Project Address: The University of Arkansas
Department of Chemistry
Fayetteville, Arkansas 72701

FINAL REPORT

Summary: This project was conducted much as it was conceived. A truck would be equipped with scientific instruments and moved from school to school so that students could get on-hands experience with instruments which are normally too expensive for a small school to purchase. A summer conference equipped the on-campus participant faculty to use the truck-laboratory properly. The lab was equipped with a power source to maintain vacuum and temperature, as required for two permanently mounted instruments. Four other instruments were drawer-mounted so that they could be moved into the participant school's permanent laboratory. Curriculum changes were strictly left up to each school, as they desired. The summer evaluation conferences deemed this project a success. Publicity involved both local and national media. The project will be financed in the future by payments by the participants.

This final report will consist of seven summary topics:

a. Conducting a summer workshop.

b. Preparation of the mobile laboratory.

c. Curriculum changes within the participating schools.

d. Movement of the truck among the participating schools.

e. Evaluation conferences.

f. Publicity concerning this project.

g. Future finances of the project.

Immediately after the project was funded, one representative from each participating school was invited to a Summer Workshop conducted on the campus of the University of Arkansas, Fayetteville, Arkansas. The purpose of this workshop was to acquaint the participants with the basic operation of the instruments, to teach them fundamental trouble-shooting techniques with the actual instruments to be used, and to provide opportunity for the participants to check the experiments they proposed to use with the mobile laboratory. These goals were met. After the passage of time it was clear that this workshop was a

major factor in the success of the project. The knowledge gained by the participants not only increased enthusiasm, but served well when instruments malfunctioned. This author strongly recommends such a training period for any similar project.

The mobile laboratory was built into the back of an 7.5' x 12' step-van. This "room-on-wheels" was heavily insulated so that temperature control, imperative for the use of some instruments, could be held constant. A gasoline-powered generator provided electrical power as the unit moved about so that the temperature could always be maintained. Two instruments were permanently mounted due to temperature and vacuum requirements. Four other instruments were fitted into detachable drawers so that they could be used inside the permanent laboratories of the participating schools, or moved independently of the mobile laboratory. In addition, jack stands were provided for the truck so that a stable base would allow the use of the usual delicate recorders.

Each school was completely free to maintain, alter, or adjust its own curriculum. No attempt was made by the larger school to coerce, or superimpose its ideas of how Chemistry should be taught. In retrospect, this principle of complete curriculum freedom is the only way to successfully bind together thirteen dissimilar schools of this type in a large cooperative endeavor. If some pressure had been brought to bear on the smaller schools to adopt a particular chemistry curriculum, many schools would have probably left the program before realizing fully whether or not benefits could be had.

A schedule for movement of the truck-laboratory was put together each year by the participants without interference of the director. The mutual give-and-take, the necessity for compromise and change, and the gains to be realized served to increase cooperative and friendship among the participants.

Initially some concern was expressed that difficulties would arise because each school would want the truck at the same time during the semester. Such is not the case, because spectroscopy is a subject which can be taught at almost anytime during the school year.

Evaluation conferences were held at the end of the summers after the first two years. An outside panel was convened so that an independent judgement would result as to the success of the project. Not only did each school have an opportunity to tell of its experiences with the project, the panel questioned each aspect of the project. In summary, the panel judged this project a success and recommended that others duplicate it.

Publicity about this project followed the usual pathways. Newspaper articles and television news coverage helped tell the story to area citizens, and thus increased the prestige (and probably enrollment) of the participant schools. One of the Kansas Colleges scheduled a "High School Day" each year in the spring to coincide with the on-campus stay of the laboratory so that area high school students would be better informed as to possible future use of the van. The director drove the van to two national meetings, one in Wisconsin, the other in California, to better inform chemists of this experiment, and its results. Finally two articles and a cover picture appeared a chemistry education journal with a world-wide audience.

The project will be financed by the participants as time passes. During the last year of operation each participant school was asked to pay $200 toward the expenses of the truck. During the next year the fee will be $500/school. The next year's fee will then be adjusted to reflect actual cost of moving the truck-laboratory on its schedule plus replacement of worn-out instruments on an amortization schedule. In this way not only will expenses be met, but new pieces of equipment can be purchased as needed as the project continues indefinitely.

APPENDIX

1. Year 1 Report
2. Year 2 Report
3. Year 3 Report
4. Year 4 Report
5. Copy of two publications on this work

REPORT: YEAR ONE

SUMMARY

The initial work on the mobile laboratory involved making decisions concerning the truck type, size, and manufacturer, and specifications of which instruments would be installed therein. The committee that made these decisions studied many hours, and then wrote careful bid requests so that the needed equipment would be provided at or exceeding specifications. Orders were then quickly placed so that much of the equipment would be available for use during the six weeks of the Summer Workshop. Local spectrometers were used to replace those that did not arrive in time.

The Summer Workshop was convened with one representative from each of the twelve participating schools. (During the Fall Semester a thirteenth school joined the group. Two of their faculty received some extra training in December.) The two goals of the Workshop were: (1) To learn to operate and teach the use of the six instruments. (2) To learn basic maintenance and simple tests designed to show causes of instrument failure, and (3) To settle the truck movement schedule and financial matters. Although the Workshop did experience some changes in scheduled events and plans, the major goals were realized. The participants returned to the home campus feeling confident that they could operate the mobile spectroscopy laboratory. The success of the truck-laboratory on its trial run during the Spring Semester shows that this view was generally true.

Preparation of the truck occurred mainly during the Fall Semester, 1975. Manufacturing and shipping holdups, design problems, and work schedule delays stretched the time required beyond the anticipated completion date. However, at the end of December enough work had been done so that the truck could be sent out on a trial run during Spring Semester, 1976. Completion of remaining construction details was postponed until Summer, 1976.

Small problems were encountered at each campus. As many as possible were corrected. The others were noted for future correction. The overall result as viewed by the participant schools was that the laboratory is a great success. Each school is looking forward to next year with enthusiasm.

I. Preparation of the Truck-Laboratory

Four stages were important in the preparation of the mobile laboratory. Initially a plan had to be formulated and decisions made concerning the type of truck which would be purchased and which instruments were to be installed therein. Then bid specifications had to be carefully written. When the bids were accepted, laboratory plans were finalized so that construction of the laboratory inside the truck could begin.

A. Early planning concerning the truck. The source of the vehicle was considered. Should a new truck be bought or should a surplus government truck be purchased? Perhaps an empty school bus body or recreational vehicle body would have been the best buy. The high cost of even a stripped school bus or recreational vehicle quickly removed either from serious consideration. Since this project was to be a testing of a new educational idea, a new vehicle rather than a used one was purchased. Then efforts were expended on the testing of the idea rather than keeping an old truck operating.

One of the referees for the proposal behind this project suggested that the U.S. Atomic Energy Commission might donate one of their old Mobile Radioisotope Laboratories. A telephone call revealed that one of these laboratories had been sitting unused for a year in a parking lot. However, Emery University was at that time trying to gain use of it. Further, many upkeep-repair problems might present themselves with this unit. Therefore no further efforts were made to use one of these vehicles.

Early in the planning stages instrument manufacturer personnel suggested that temperature control was a very important consideration for operation of a nuclear magnetic resonance spectrometer. Local refrigeration-heating experts suggested three-to-four inches of insulation would be required to withstand serious temperature changes during the cold winters of Kansas and the hot summers of Arkansas. This means that the width, heighth, and length of the truck cargo area would effectively be shortened by 8 inches from the measurements when the truck was purchased due to installation of the insulation. Only one manufacturer, General Motors Corporation, sold a truck at that time with a body height and width of 96 inches. Once eight inches was subtracted from the height of other brands the usable height which remained fell below six feet. Therefore this one requirement narrowed the selection to a Chevrolet brand.

Dual rear wheels and an aluminum body were purchased in order to be sure the weight could be carried safely for long time periods and to eliminate rust during later years of operation. Many different drivers and a heavy cargo made an automatic transmission and heavy duty shock absorbers essential. In addition, a steel mesh partition with a sliding door between the driver compartment and the cargo area provided a safety measure in case of an accident. A step-van-type truck provided the best approximation to a "room on wheels", one of the objectives. In summary, a truck with heavy duty safety features was purchased as wide and as tall as possible in order to provide the experience of a laboratory in a truck.

The bids were opened for the truck after all Chevrolet trucks had been manufactured for the 1975 year. Unfortunately a truck with the needed eight foot cargo area width and all of the other specifications was not available. However, a truck with a ninety inch wide cargo area was found which also was equipped with all of the other essential specifications. A truck with ninety-six inch wide cargo area could have been had by waiting until Fall for a 1976 model. However in addition to at least a 4 month delay the price would have been ten percent higher. This was unacceptable. The slightly narrower model was accepted. Later, this reduction in width coupled with a relocation of the generator caused a narrow fit of a cabinet at the rear of the truck.

B. Decisions concerning Instruments. A questionnaire obtained prior to submission of the proposal for this project indicated that six instruments were needed by most schools to be served by the project: a grating infrared (ir), ultraviolet-visible (uv-vis), atomic absorption (aa), nuclear magnetic resonance (nmr), and mass (ms) spectrometers and a flame-ionization gas-liquid chromatograph (glc). Thus a committee composed of T.D. Roberts, R.P. Quirk, and K. McElveen carefully scrutinized manufacturer specifications and prices for these six instruments. Occasionally oral discussions with factory personnel added valuable information. After this inquiry was over, specifications were written so as to obtain the best instruments available in the price range, or equivalent.

1. Grating Infrared Spectrometer. Several schools have prism infrared spectrometers. These less expensive instruments prohibit certain studies; for example, of hydrogen bonding in organic compounds. To expand the capabilities of those schools with prism instruments and to provide a rugged, useful spectrometer, a grating instrument was purchased. In addition to the usual specifications the following were thought be desirable: Non-hydroscopic optics, germanium lens thermocouple detector, nichrome wire source, three scan speeds, abscissa scale expansion, accuset meter for precise gain control setting, solid state electronics with pull-out circuit boards, external ordinate scale expansion, and chemically resistant case.

2. Ultraviolet-Visible Spectrometer. Most manufacturers supply a single instrument which will give either ultraviolet or visible spectra. This instrument type was sought for the truck-laboratory. In addition to the usual specifications a digital readout unit which could also be used as a digital voltmeter was thought to be an important advantage. Solid state electronics and pullout circuit boards were available on all models.

3. Atomic Absorption Spectrometer. The unit desired should have integrated reading capabilities with three and ten second integration times, peak reader capability, curve correction, and zero setting in addition to the usual specifications. Integral gas controls, meters, and push button flame ignition was included. Since several companies manufacture suitable units, these specifications were kept general.

4. Flame Ionization Gas-Liquid Chromatograph. Although several schools had gas-liquid chromatography capability, their units provided only the less sensitive thermal conductivity detection, unually at less than optimum high temperatures. In addition these low cost units often are in need of repair. For these reasons a rugged flame ionization detection unit was purchased. Independent control and monitoring of the temperature of the injector, the oven, and the detector was specified. The usual specifications included a large oven (8" x 7.5" x 6.5") and high sensitivity (1×10^{-11} amps/mV) coupled with long term stability (10 uV/mo.) of the solid state electrometer.

5. Mass Spectrometer. Since only one supplier provides a lower cost unit, specifications were drawn for a Varian EM 600 unit.

6. Nuclear Magnetic Resonance Spectrometer. A referee for the proposal behind this project suggested that one or two 30 MHz instruments would serve the needs of this project. This suggestion was rejected for two reasons: 1) Friends at Henderson State University, Arkadelphia, Arkansas, report extreme sensitivity of the 30 MHz unit to minor temperature variations. (Only one company manufactures 30 MHz units.) Such is incompatible with operation in a truck. 2) Most books and the research literature record nmr spectra at 60 MHz. This fact causes additional teaching and understanding problems if a 30 MHz instrument is being used. Therefore a 60 MHz spectrometer was purchased.

The specifications for this instrument were written around the EM-360 unit for two reasons: 1) Friends at Southern State College, Magnolia, Arkansas, purchased the alternative possibility, a Perkin-Elmer R24 spectrometer, and found that an extra wooden shield in an air-conditioned room was necessary for stability. Again, such is not compatible with operation in a truck. 2) We own a Varian EM-360 unit here at the University of Arkansas and are familiar with its reliability. This should be very helpful in servicing and repairing the unit.

Opening of the bids revealed that a small saving could be realized by purchasing five of the six instruments from one supplier. Since this company promised to deliver all of these instruments by August 15, 1976, at the latest, orders were immediately placed. Unfortunately none of these promises were fulfilled. Every instrument was at least one week late. The uv-vis is currently one year late. (A demonstration model is being used.) The ms was about four months late. The other instruments ranged up to one month late. If anything can be learned from this experience, it is that instrument salesmen are cooperative, friendly, and probably sincerely interested in providing proper service and sales. However, the people behind the salesmen are not to be trusted and will provide embarrassing delays.

C. Alterations to the truck.

Initial plans called for mounting the air-conditioner/heater on the roof of the truck and the electricity generator beneath the floor on the right rear side. Thus a constant temperature could be maintained in the truck cargo area during travel. Before these objectives could be realized, substantial alterations were necessary.

The truck was manufactured with only skimpy bracing to hold up the roofing which was only as thick as 1 sheet of aluminum. An air-conditioner which was heavy enough to do the necessary cooling in the summer would soon vibrate so much as to fall through this thin roofing. Therefore, the first alteration involved using 2" x 4" studs to brace and reinforce the walls, ceiling, and floors. The spaces in the walls, ceilings, and floors in between the studs were filled in with insulation. Insulation was also installed on the back doors. The wire mesh screen in front of the cargo area was reinforced by the same type 2" x 4" studs and insulation. A double glass panel with a dead air space between the glass sheets was attached to the sliding wire mesh door that separates the cargo compartment from the driver. Thus the space which was to become the laboratory was first heavily insulated and reinforced for structural strength. In retrospect, this expensive constructional activity probably was the single most important feature to insure successful operation of the nmr, one of the most desired instruments of the laboratory.

The air-conditioner/heater is of the type which is used in recreational vehicles. The heating-cooling capacity is 11,000 B.T.U./hour. Modification of the controls allows the temperature sensing unit to either heat or cool as required. On a mild day as few as three people will cause the cooling unit to be activated. During design of this unit, heat sources such as the nuclear magnetic resonance and mass spectrometers were considered. In addition, the fluorescent light contributes some heat to the laboratory. The air conditioner was mounted on the top in the center of the cargo area so as to provide efficient heating and cooling.

The nuclear magnetic resonance spectrometer magnet weighs 600 pounds. Once its location in the truck was determined, safety factors were considered. Suppose a sleepy driver hits a cement obstacle at 60 miles per hour? Probably the wire mesh plus the 2" x 4" stud partition between the driver and the magnet would not stop such a heavy object from crashing through. If the driver survived the accident, he might still be crushed by the magnet. Further, suppose the truck overturns and skids to a halt. The magnet might not hit the driver,

but would smash around in the cargo area. In fact, a loose magnet might do much more financial damage than that experienced by just an overturned truck. The truck could be uprighted and might experience only minor damages; but a loose magnet could ruin several delicate electronic instruments inside the laboratory. Therefore, two chains were passed through two large convenient holes in the base of the magnet an attached with heavy hooks through the floor. Unfortunately, the floor of the truck is made of aluminum which could be easily torn apart. Accordingly, a sheet of steel was attached underneath the truck to which the chain hooks are fastened. If the magnet gets loose from this firm mooring, a major catastrophe will have occurred.

After the director made careful measurements and drawings, the cabinets were fashioned by a University carpenter. The larger cabinet was designed to house large drawers which contain the smaller instruments. The drawers were constructed at least two inches larger in each dimension than the instruments which would go therein. Then two-inch foam padding was glued to each side and three-inch foam padding to the bottom of the drawer. Further, a two-inch piece of foam was placed across the top of the instrument. In this way, each of the four smaller instruments are completely surrounded by foam padding during movement of the truck. Handles were cut into the ends of each drawer which houses an instrument. Thus, a drawer can be pulled out and carried into the Chemistry Building before the instrument is removed. The small cabinet allows the nmr console, decoupling unit, and oscilloscope to ride on three inches of foam.

Once the location inside the truck of nmr magnet was determined, the wheels on the base of the magnet console were removed and a four inch piece of foam was placed underneath the plywood base on which the console sits. However, the usefulness of this foam may be minimal since the weight of the magnet crushes it to approximately 3/4". The console of the nmr was easily installed since only 110 volt power was needed. This power was provided by placing several outlets along the left and right walls. Except during movement of the truck, an extension cord provides electricity from commercial mains. The light fixture was fastened to the ceiling near the left side to provide close proximity to the power source and to be sure the head of the tall person would not bump it. To complete the equipment needed for the nmr, the air pump was located in an unused space on the floor underneath the driver. This removes the noise of the pump motor from the laboratory space. A plastic tube delivers air through the wire mesh wall to the magnet as required.

The electricity generator was added so that the truck will have power to the instruments and to the heater-cooler while traveling. A convenient space below the floor and behind the right dual rear tires proved to be too small. Unfortunately, this fact became known after the cabinet for both the nmr and the other instruments had been installed. The only remaining space was found to be on the left side at the rear above the floor. A hole was cut in the left side to provide both intake air for the motor and access for servicing. The generator space was then covered with insulation and wood facing.

Early during planning of the laboratory, thought was given to weight distribution. The heavy magnet on the left side was to be balanced by the other instruments, the cabinet, and the generator on the right side. When the generator had to be moved to the only available space on the left side, an imbalance occurred. This was easily corrected by use of jack stands (see below) when the

truck is parked. However, during travel the truck's imbalance can be felt by the driver. Power steering and heavy duty springs minimize this problem, but do not completely eliminate it.

The mass spectrometer console and magnet was attached to the cabinet top over three-inch foam padding. A copper tube vacuum line was passed from the spectrometer through the wall, over the wire mesh sliding door and to an unused area on the floor underneath the driver and attached to a vacuum pump which was bolted down. Again, this location effectively removes noise from the laboratory area.

A series of smaller cabinets for storage purposes were fastened to the ceiling and right wall over the larger cabinet.

During checkout of the nmr a perplexing problem was found. For some reason, the recorder would produce an approximately two cycle per second sine wave regardless of sample, mode of analysis, or buttons pushed. Careful analysis showed that this signal existed in every stage from the transmitter to the recorder. Finally, a small rocking motion of the truck over long time periods was determined to be the cause of this apparent signal on the recorder. Jacking up the truck and putting four jack stands under the two center structural beams removed this problem. Putting the jack stands under the axles is ineffective since the truck is still suspended on springs.

Early it was imagined that an ideal method for one person to move the laboratory would be to use a tow-bar to pull a car behind the truck. After driving to the participant school, the driver could return home in this extra car. Only the director of this project opted to follow this procedure. However, even he abandoned it after a near serious accident when the tow-bar became loose, and after twice almost ruining the automatic transmission of his car. Due to the weight of the magnet, the truck is imbalanced to the left side. Further, the truck is over 25' long. Adding a tow-bar and automobile provides a very long procession that does not easily navigate a sharp corner. Since neither the director nor any of the participant school coordinators are professional truck drivers, the practice of towing a car is abandoned and not recommended.

II. <u>Summer Workshop</u>

One of the best ideas utilized in this project was the six weeks Summer Workshop. Mainly efforts were directed toward familiarizing participant school coordinators with the theory, operation, and maintenance of the six intruments and establishing ways and means of cooperating both in scheduling and paying for the operating of the truck. Although the three major goals were accomplished, several side effects were important and are discussed below. During the workshop no efforts were made to coerce any school to use any instrument or any given experiment. Each school was left completely free to direct its own program, to choose the instruments utilized, and to decide which experiments, if any, were appropriate for its students. This important fundamental tenant remains as a basic ingredient of this project.

Initially several small changes were made in arrangements for the Summer Workshop. Because the proposal behind this project was submitted at such a late date, the project did not begin as early as would have been optimum. One of the participant school coordinators was forced to commit himself to a summer job and could only attend two weeks. Two others could only attend for five of the six weeks. The major instrument supplier had promised to provide about three weeks of instruction, help, and teaching concerning the instruments. Over one-half of this three-week period failed to materialize. Adjustments were made by the director so that the workshop could accomplish its goals.

The purpose of the workshop was to familiarize the participant school coordinators with the operation of the instruments and the laboratory so that upon arrival of the truck on campus, optimum utilization would occur. This was done for each instrument following a five-point plan. First, lectures were presented on theory, both as to how the instruments function and as to how the instruments are used in chemistry. The participants then began to get experience in setting up and operating the instruments. Several demonstrations of possible undergraduate experiments which used a particular instrument were then presented. Next, each participant engaged in a round-table, open discussion of the use of the instrument on his campus. Notes were taken. Questions were asked. References were given. Most felt such discussions were very fruitful and stimulating. Finally, a list was composed of small items which would be needed when the truck-laboratory arrives on campus. Such items as chart paper, recorder pens, and sample containers will not be routinely supplied on the truck due to the ease with which they are misplaced. Surprisingly, the cost of these items mounts rapidly for a school which has no previous laboratory use of an instrument. Some schools faced initial costs of four hundred dollars, especially since several year's supply were often purchased in order to take advantage of bulk purchasing.

Maintenance and prevention of instrument failure was an important concern of the workshop. In the experience of the director most of the problems with instruments are due to either a trivial problem or to lack of understanding of how the intrument functions. Therefore, the first primary area of emphasis, designed to prevent instrument malfunction, was to be sure that the participants have a sound knowledge of the instrument and the technique involved. This training is probably a major factor in any success enjoyed by the laboratory.

A few days were set aside for elementary instruction in electronics by K. McElveen. The plan was to teach the participants enough to use a voltmeter intelligently to make checks on these instruments. In this way, the participant would not hesitate to remove the cover and make checks so as to isolate the malfunction to a particular area. Then perhaps a faulty circuit board can be isolated and quickly repaired. Some of the manufacturer manuals supplied with the instrument contain lengthy trouble shooting guides. Not only do these contain voltage checks at key points, but other kinds of checks and procedures for determining where a problem lies. Most of these problem areas were noted and checked during the summer. For example, movement of instruments often shakes loose circuit boards from their connections. Removal of a cover quickly shows which one has jarred loose. Each of the voltage checks were illustrated to the participants.

A third important function of the Workshop was to find methods of cooperating together. The participants elected to establish a schedule for the truck separate from any influence of the director. The results are shown in Table 1. This compromise schedule seemed to provide the truck at a time which would be useful to each school. In addition, the University of Arkansas agreed to pay for the gasoline and oil for the truck during the year and then divide up the amount among the schools for repayment during the summer.

TABLE 1

LABORATORY MOVEMENT DURING SPRING 1976

Dates - 1976	Location	Coordinator
January 5 to February 5	Tabor College, Hillsboro, KS	W. Johnson
February 5 to February 13	Sterling College, Sterling, KS	A. McAllister
February 13 to February 20	Kansas Wesleyan University, Salina, KS	Y.C. Chiang
February 20 to February 27	Bethany College, Lindsborg, KS	M. Mitchell
February 27 to March 5	McPherson College, McPherson, KS	R. Zerger
March 5 to March 13	Bethel College, N. Newton, KS	T. Lehman
March 15 to March 20	University of Arkansas, Pine Bluff, Pine Bluff, AR	W. Willingham
March 22 to March 27	John Brown University, Siloam Springs, AR	J. Holliday
March 27 to April 3	Ouachita Baptist University, Arkadelphia, AR	W. Everett
April 3 to April 10	University of Arkansas, Monticello, Monticello, AR	W. Godwin
April 10 to April 17	Harding College, Searcy, AR	E. Wilson
April 17 to April 24	Arkansas College, Batesville, AR	V. Kirk
April 24 to May 12	College of the Ozarks, Clarksville, AR	M. Condren

Much discussion concerning the contents and arrangements of the truck-laboratory ensued. Many valuable suggestions were made to the director from the participants concerning construction of the truck-laboratory.

Finally, there were a number of extra benefits of the Workshop which were not planned or necessarily expected. For example, every participant spent more than forty hours per week in workshop studies and other chemistry projects. Many worked at night and on Saturdays. One from Kansas and another from Arkansas found common interest in a new atomic absorption experiment for undergraduates and worked out the details. This work is to be published soon. A number of discussions of teaching methods and topics were organized for evenings. Much informal idea exchange occurred. A University of Arkansas faculty member came in one night to illustrate how to make very inexpensive lecture slides. Thus a common sharing of problems and solutions forged a spirit of comradeship previously unknown. No longer did the larger school remain aloof while the smaller schools each went separate ways. Here was a new spirit of working together that was truly enjoyable.

The project director now stands ready to help other similar projects with initial workshops. For bare expenses an on-site visit with prospective participant schools for new projects could impart much information.

III. Addition of a Thirteenth School

Before submitting a proposal a number of schools were queried as to their interest in being a part of the project. Due to a misunderstanding, the Chemistry Department of the University of Arkansas at Pine Bluff did not indicate any interest in this project. However, in a chance meeting, the true nature of the project was made clear and a request was made to be a part of the project. Therefore, the University of Arkansas at Pine Bluff was invited to become one of the participant schools. The Head of the Chemistry Department and one other faculty member came up during December for instruction in the use of the nmr, the atomic absorption and the mass spectrometers. Then during the Spring Semester the truck visited their campus for the usual one week period.

IV. Trial Run, Spring, 1976: The First Visits of the Mobile Laboratory to the Campuses of the Participants

In January, 1976, the decision was made to send the truck on a trial run even though several coats of varnish were lacking, the carpet was not yet installed, a make-shift door had been fashioned for the generator, and a chair was not available for a passenger. (The manufacturer did not deliver the door for the generator compartment as promised.) The schedule in Table 1 allowed the truck to visit every participant school for at least one week.

At several colleges the filament of the ms failed. When fewer samples of heavily halogenated, highly volatile hydrocarbons were injected the filaments lasted much longer. A second solution to this problem was sought along financial lines. New filaments from the manufacturer cost $69 plus postage and often are delayed several months before delivery. Therefore a small supply of the correct diameter rhenium wire was purchased and several attempts were made to learn to fashion shop-made filaments. This project was a success. Filaments can now be made for less than one dollar. Therefore, several filaments will travel with the truck at all times. When one fails, another can be substituted. The broken filament can then be mailed to the director for repair.

Other problems which were encountered were minimal. At several schools fuses or circuit breakers failed. Next year larger amperage lines will be used. Some schools felt that too many instruments arrived at one time. This problem can be solved by allowing the smaller instruments to circulate semi-independently of the truck in private cars. The time involved in setting up the truck caused some to decide to have the truck on their campus once for two weeks rather than at two different times for one week each. Problems of this kind will be worked out as they occur.

V. Dissemination of Information

During the first year of this project, a minimum amount of information was disseminated because so much of the problem remained to be done. In January, 1976, a National Science Foundation project director's meeting near Washington, D.C., allowed the director to briefly outline the project and its goals before a small interested audience. A few members of the audience asked for and did receive additional information.

The usual news media publicity had been obtained. Local newspapers appear to be interested in the idea and its solution. A brief news note in Journal of Chemical Education brought forth a few inquiries for information. In short, during the first year, the usual informational publicity has been put forth for a novel idea which remains to be proven.

During the early stages of this project a telephone call from Professor Dave Smith, Doane College, Crete, Nebraska, allowed much information to be exchanged about the project. A cooperative venture similar to this one is envisioned for the Nebraska area. This project stands ready to help in any possible way.

Future plans call for much more discussion of the project. A poster paper and truck demonstration are scheduled for the Fourth Biennial Chemical Education Conference, August 8-12, 1976, Madison, Wisconsin. The same is planned for San Francisco, August 29-September 3, 1976, at the National Meeting of the American Chemical Society. This latter paper is part of a "Symposium on the Economics of Undergraduate Laboratory Programs". Acceptance of this paper represents a minor significant achievement for this project.

Grant #: SED75-14376
University of Arkansas
Grant Director: T.D. Roberts

USE OF BUDGETED FUNDS, YEAR ONE
June 1, 1975 - May 30, 1976

		Budgeted	Spent	Encumbered
I.	Instruments (Includes 3% sales tax and shipping)			
	a. Spectrometers			
	1. Nuclear magnetic resonance	15,820	17,142.98	
	2. mass	10,170	0.00	7,423.30
	3. infrared	6,780	4,852.59	
	4. ultraviolet	9,492	0.00	6,684.20
	5. atomic absorption	7,910	5,949.90	
	b. Chromatograph	3,955	2,566.90	
	c. Parts, tools, etc.	10,735	1,897.18	
	d. Audio-slide projector	1,130	1,024.85	
	e. Manuals	565		
	Total	66,557	33,434.00	14,107.50
II.	Truck			
	a. Purchases	7,663	6,788.64	
	b. Alterations	2,781	6,061.89	
	Total	10,444	12,850.53	
III.	Salary-Wages			
	a. Director	9,300	8,738.02	
	b. Senior faculty assistant	2,460	3,281.00	
	c. Graduate Assistant	6,000	5,420.00	
	d. Secretary	1,200	1,209.00	
	e. Participant school coordinators	12,000	11,333.00	
	f. Fringe benefits	3,096	2,114.00	
	g. Indirect costs	15,864	16,074.00	
	Total	49,920	48,169.02	
IV.	Maintenance, Insurance			
	a. Parts			
	1. Instruments	300	0.00	
	2. Truck	200	0.00	
	b. Insurance	2,000	1,041.00	
	Total	2,500	1,041.00	
V.	Travel			
	a. Director	800	290.14	
	b. Participant Coordinators	12,756	12,286.41	
	c. Repair trips	200		
	Total	13,756	12,576.55	
	Grand Total	143,177	108,071.10	

REPORT: YEAR TWO

SUMMARY:

The summer was largely spent correcting small problems found during the first half year of operation, completing minor construction projects which had been suspended while the truck was in circulation, and displaying the truck-laboratory at two national meetings: the Fourth Biennial Conference on Chemical Education, August 8-12, Madison, Wisconsin, and the 172nd National Meeting of the American Chemical Society, August 30 - September 3, San Francisco, California. Widespread interest was evident.

The academic year involved the first evaluation conference and the first regular year of truck use. The panel of outside experts as well as the coordinators of the participant schools indicated during and after the conference that the first year was a success. During the second year of operation of the truck-laboratory a number of small problems appeared. Solutions for these problems are planned during the third year.

During the third year plans will be finalized to put this project on a self-supporting basis and to publicize further the results of this experiment.

I. Other Construction Work on the Laboratory

During the Summer of the second year several suspended construction projects were completed. Carpeting was installed as a floor covering and as a deterrent to heat flow in the cab area. A door was fashioned to replace the makeshift door over the generator. The sign was completed by adding the names of the participating schools.

During the Spring installation of a solid sample inlet and a gas sample inlet completed the mass spectrometer facility. Because the supplier could not provide a new model the cost of the demonstrator ultraviolet-visible spectrometer which had been initially shipped was reduced by 25%. Although this unit is dented and scratched, performance is good.

II. Dissemination of Information Concerning this Experiment

Three meetings were attended during the year and an oral paper or poster paper presented at each. During the summer the truck-laboratory was driven to Madison, Wisconsin, and displayed on the campus of the University of Wisconsin during the 4th Biennial Conference on Chemical Education. About 200 attendees visited the truck and accompanying poster paper. Additional information was supplied for all who requested it. At the end of the summer the laboratory was driven to San Francisco and displayed outside the Convention Center during the 172nd National Meeting of the American Chemical Society. More than 1000 visitors viewed the laboratory. Some requested additional information which was later sent by mail. In the Spring the director presented a paper on this project at the 173rd National Meeting of the American Chemical Society in New Orleans. The titles of these papers and the meetings are summarized below in Table 1. An abstract of each is attached to this report.

TABLE I

Oral Presentations of the Work of this Project

Date	Meeting Title	Paper Title
8/8 - 8/12	4th Biennial Conference on Chemical Education	One Idea and One Truck after One Year: Problems Associated with Construction and Operation of a Cooperative Mobile Spectroscopy Laboratory
8/30 - 9/3	172nd National Meeting, A.C.S.	A Mobile Spectroscopy Laboratory as a Cost Cutting Venture
3/20 - 3/25	173rd National Meeting, A.C.S.	Chemistry in a Mobile Spectroscopy Laboratory

During the meeting in Wisconsin a reporter from "Chemical and Engineering News" obtained information and pictures which subsequently appeared in the September 6, 1976, issue. During the San Francisco meeting staff members from Varian Associates did likewise. An article describing this work then appeared in their company publication, "VIA", Volume 10, Number 3, 1976.

During late Spring a writer for "Mosaic" visited the campus of the College of the Ozarks with the director in order to prepare a story on the truck-laboratory experiment.

A number of inquiries by individuals were made and answered by the director during the year.

III. The First Evaluation Conference

The first evaluation conference was held on September 17 and 18 with the independent evaluation panel: Professor W.T. Lippincott, K. Takemura, and C. VanderWerf. Minor problems and the yearly schedule were discussed among participants during the Friday session. On Saturday a report by the director and the participating schools were made to the panel. After their independent deliberations a joint meeting was held to receive their comments. Mainly the panel was complimentary. However, they did stress that the group should look to the future and asked what new programs or ideas were to be developed. Further each school was encouraged to think of uses of the truck with local chemical industries.

The schedule which was devised by the participants for the academic year is depicted on the following page.

TABLE II

1976-1977 Schedule for the Truck Laboratory

10/3	University of Arkansas at Pine Bluff
10/10	University of Arkansas at Monticello
10/17	Ouachita Baptist University
10/24	College of the Ozarks
10/31	John Brown University
11/13	Sterling College
11/20	Bethel College
11/27	Kansas Wesleyan University
12/4	McPherson College
12/11	Tabor College
1/2	Sterling College and Bethel College
2/5	Kansas Wesleyan University
2/12	Tabor College
2/19	McPherson College
2/26	Sterling College
3/5	Bethany College
3/20	Harding College
4/3	Arkansas College
4/10	University of Arkansas at Pine Bluff
4/17	University of Arkansas at Monticello
4/24	Ouachita Baptist University
5/1	College of the Ozarks

IV. The First Full Year for the Truck-Laboratory

During the year a number of small problems were experienced. Chiefly these were solved by a trip of the teaching assistant to the site and/or repair by personnel at the site. Only time will tell as to whether these re-occur yearly and at a rate so as to be discouraging. In the main the participating schools continue to be pleased with the project and to look forward to its continued use.

V. Future Plans

During the third year final plans will be made to put this project on a self-supporting basis. Further, all concerned agree that the spirit of cooperation that has resulted from this project should be enlarged. Therefore efforts will be put forth to find new and better ways to cooperate for our mutual benefit.

VI. Use of Budgeted Funds: Year Two

June 1, 1976 - May 30, 1977

		Budgeted	Spent
I. Maintenance, Insurance			
A. Instruments, parts		$ 400	$ 125,05
B. Truck maintenance		200	195.86
C. Insurance		1,850	1,092.00
D. Unspent from Year 1		1,459	--------
	TOTALS	$ 3,909	$1,412.91
II. Salaries, Wages			
A. Director		$ 5,600	$5,940[a]
B. Graduate Assistant		4,800	4,830
C. Secretary		1,200	287.86[b]
D. Fringe Benefits		1,160	826.80
E. Indirect Costs		5,944	5,675.53
F. Unspent from Year 1		1,750.98	--------
	TOTALS	$20,454.98	$17,560.19
III. Travel			
A. Director		$ 800	$1,242.38[c]
B. Participants to Conference		1,000	706.82
C. Panel		1,000	696.15
D. Graduate Assistant Repair Trips		200	88.14
E. Unspent from Year 1		1,179.45	----------
	TOTALS	$ 4,179.45	$2,796.93
IV. Instruments, Truck Unspent from Year 1			
A. Instruments			
Mass Spectrometer		$10,170	$7,646[d]
Ultraviolet-Visible Spectrometer		9,492	5,239.38[d]
B. Parts, Truck		11,054.47[e]	
Parts			599.49
Truck Alterations			546.85
	TOTALS	$30,716.47	$14,031.72
Total Expenditure			$35,801.75
Funds Remaining as of 6/1/77 (includes 25,594 for year 3 budget)			$49,127.22

Notes:

a Includes some year 3 salary due to the year three summer school beginning May, 1977, instead of June as anticipated.

b Does not include the remainder of the secretary salary which will appear next year due to slow posting by our accounting department.

c Includes expenses of two trips where the truck was driven and a display set up.

d Includes state tax.

Comment:

Funds have been used for the purposes budgeted.

REPORT: YEAR THREE

SUMMARY:

In addition to normal activities (see previous reports for a summary of these activities) this year was marked by unusual publicity, an on-site visit by Dr. John Snyder, the National Science Foundation project coordinator, and a major decision concerning future financing of the project. After all factors are considered, the year can be termed on outstanding success.

The Usual Activities Summarized

As usual the truck schedule was composed at the yearly meeting by the on-campus coordinators as a function of their needs and desires. During this year some 200 chemistry majors used the instruments in the mobile laboratory to do chemistry experiments. More than 400 non-chemistry majors were given demonstrations of the use of these instruments as part of their science courses. The schedule of use of the laboratory during this year was as follows:

Week of:	School
10/9-10/23	Ouachita Baptist University
10/26-10/30	University of Arkansas, Monticello
11/6	College of the Ozarks
11/13	Repair-Clean Up Week (U of A)
11/17-12/3	McPherson College
12/5	Vacation - Tabor College
Interterm (Jan.)	Kansas Wesleyan University
1/30-2/3	McPherson College
2/6-2/17	Sterling College
2/20-3/3	Bethel College
3/6-3/17	Bethany College
3/20-3/25	Repair-Clean Up Week (U of A)
3/25-4/11	John Brown University
4/8-4/15	University of Arkansas, Pine Bluff
4/22	University of Arkansas, Monticello
4/29	Arkansas College - Harding College
5/6	College of the Ozarks

During the Spring of the year the mass spectrometer functioned intermittently. The other instruments operated as expected. Obviously some attention must be given to the mass spectrometer to correct its malfunctions.

Publicity

Three unusual and significant publicity items occurred during this year. First, an article appeared in the September/October issue of Mosaic. Significant comments of approval were received from several chief administrators of the smaller schools associated with this project as a result of the article. Later during the Fall the director of this project was invited to be the after-dinner speaker at the yearly meeting of the Great Plains Association of Chemistry Teachers in Liberal Arts Colleges. Many questions were answered.

Encouragement was given to a group of schools in Nebraska which are planning a similar project. (This project was subsequently funded by the Dreyfus Foundation.) Finally, two articles written by the director were accepted and published in the Journal of Chemical Education. This latter publicity brought on a rash of individual letters followed by mention of the project in a summary article in Chemtech.

On-Site Visit

During September, Dr. John Snyder, Program Director, Modes Development Program, visited the project site and learned first hand about our problems, the solutions, and the future work to be done. Much useful discussion ensued, especially concerning future financing of the project.

Future Finances

A significant decision was reached and put into action concerning the future method of generating funds for the project. During the 1978-1979 academic year each participating school will be assessed a fee of $200. This fee will go up at least $500 for the 1979-1980 academic year. Thereafter, the fee will be assessed as a direct function of expenses plus a set amount to replace unrepairable instruments. In this way the project will be self-supporting.

Use of Funds: Year Three (June 1, 1977 - May 30, 1978)

Funds were expended in the following way during the year:

I. Maintenance, Insurance			
A. Instruments, parts		$ 255.47	
B. Truck Maintenance		257.51	
C. Insurance		983.00	
	TOTAL	$ 1,495.98	
II. Salaries, Wages			
A. Director		$ 4,551.00	
B. Graduate Assistant		5,040.00	
C. Secretary		100.00	
D. Fringe Benefits		664.93	
E. Indirect Costs		5,417.13	
	TOTAL	$ 15,773.06	
III. Travel			
A. Director		$ 1,153.87	
B. Participants to Conference		954.02	
C. Panel		417.16	
D. Graduate Assistant Repair Trips		90.23	
	TOTAL	$ 2,615.28	
IV. Parts		$ 1,415.39	
	Total Spent	$ 21,299.71	
	Balance from Year 2		$ 49,127.22
	Balance on Hand 6/1/78		$ 27,827.51

Continued Use of Unexpended Funds

During the latter part of the year a request was made to the National Science Foundation to allow unexpended funds to be used during the fourth year of operation. This request was granted.

REPORT: YEAR FOUR

SUMMARY:

This year was marked by unusually easy use and response of five of the six instruments and unusual difficulty with the sixth, the mass spectrometer. Two of the schools dropped out of the program.

Normal Activities

The schedule for movement of the truck-laboratory was composed by telephone and letters in August by the director and confirmed at the yearly meeting in October held in conjunction with the Midwest Regional Meeting of the American Chemical Society on this campus. During this year over 100 chemistry majors and more than 200 non-chemistry majors utilized the laboratory as part of their training in chemistry and science. (This number is down some from last year due to withdrawal by two schools and some difficulties with the mass spectrometer. See below.) The scheduled use of the truck-laboratory is as follows:

Week of:	School
10/8-10/12	Harding College
10/15-10/19	Ouachita Baptist University
10/22-10/27	University of Arkansas, Monticello
10/29-11/2	College of the Ozarks
11/5-11/16	John Brown University
11/19-11/22	Repair-Clean Up (if needed) (U of A)
11/26-12/15	Sterling College
12/7-12/29	Christmas Break
1/2-1/27	Tabor College
1/28-2/9	Bethel College
2/11-2/23	McPherson College
2/25-3/9	Bethany College
3/12-3/17	Repair-Clean Up (if needed) (U of A)
3/18-3/24	Ouachita Baptist University
3/25-3/31	University of Arkansas, Monticello
4/1-4/14	University of Arkansas, Pine Bluff
4/15-4/21	Harding College
4/22-4/29	College of the Ozarks

The actual movement of the truck varied a bit from the above schedule due to malfunction of the mass spectrometer. (See below.)

Financial Considerations

At the beginning of this year a fee of $200 per school was assessed. About this time two schools withdrew from the project. Kansas Wesleyan University stated that they were withdrawing due to an adverse financial situation caused by declining enrollment. However this school already owns, and thus duplicates, several instruments like those on the truck and obviously has

decided that they do not necessarily need the other instruments. Arkansas College obtained a N.S.F. grant to purchase all but one of the instruments which they did not own and which are found on the truck.

The fee will be raised to at least $500 per school next year. Already Harding College which also purchased several new instruments recently has indicated that they will no longer be part of the project. Two other schools have recently purchased nmr spectrophotometers. They will probably drop out of the project. A decision as to whether these schools should be replaced by other schools will be made in the near future.

Probably the project originally contained too many schools. If the number can be maintained at 8 or 9, each school could use the truck for about one month. Many advantages accrue by increasing the resident time of the mobile laboratory in this way.

Difficulties During This Year

From the beginning the mass spectrometer gave problems. The initial problem seemed to lie with the operators not knowing how to use the instrument properly. When the truck would be returned to this campus an experienced operator could reset the controls (often these controls were hopelessly misaligned) and get satisfactory spectra. We hope to solve this problem by further operating instructions, as applicable. Later the ~~mass~~ spectrometer did not function at all. Later the mass spectrometer did not function at all. This was found to be due to a problem with maintaining a high enough vacuum. This will be corrected by changing valves and gaskets when the problem is noted. Although these problems are worrisome, they are not deemed insurmountable. Surely the mass spectrometer will be functioning next year.

During the Spring Semester one other unusual problem delayed the truck somewhat. An electrician defied his instructions and hooked the power cable of the laboratory to a 220 V source instead of the needed 110 V. A small fire ruined the air conditioner-heater. Our insurance policy covered the bulk of the expense. Surely this problem will not occur again!

Future Work

Excitement continues here for the use of the mobile laboratory to provide training that cannot be had otherwise. Plans are being laid to possibly utilize the van to reach even to high schools as an aid in science instruction at this level.

Use of Funds: Year Four (June 1, 1975 - May 30, 1976)

In accord with the budget submitted and approved earlier, funds were used in the following way:

I. Maintenance, Insurance

A. Instruments	$ 4,646.06
B. Truck	9,335.76
C. Insurance	1,065.53

II. Salaries

A.	Director	$ 6,111.00
B.	Graduate Assistant	3,700.00
C.	Secretary	0.00
D.	Fringe	980.83
E.	Indirect	1,027.73

III. Travel $ 329.48

IV. New Instruments $ 490.00

Total Spent - Year Four	$ 27,686.39
Amount Returned to NSF	$ 141.05
Balance on hand	$ 0.00

YEAR ONE	$ 108,071,10
YEAR TWO	35,801.75
YEAR THREE	21,299.71
YEAR FOUR	27,686.39
TOTAL	$ 192,858.95

Make \$1 Do the Job of \$2... or \$3... or \$4 in Purchasing Needed Large Instruments: Cooperation via a Mobile Spectroscopy Laboratory as a Way of Life for Large and Small Schools

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ABSTRACT

As a means by which smaller colleges acting on a cooperative basis with a larger school can obtain access to more expensive instruments a step-van truck was converted into a mobile laboratory and equipped with 60 MHz proton magnetic resonance, ultraviolet-visible, grating infrared, atomic absorption, and mass spectrometers and a flame ionization gas-liquid chromatograph. This laboratory now circulates on a yearly pre-arranged schedule among thirteen participating colleges stopping for one or two week periods so that their students can use these instruments to do locally determined experiments under supervision of their regular on campus instructors as part of their on-going chemistry curriculum. Pre-arrival lectures prepare the students for this period of intense data gathering. Much data analysis can take place after the laboratory moves to another campus.

A summer workshop was utilized to acquaint the participant on campus coordinators with each instrument, to test possible experiments, and to learn basic maintenance and trouble shooting techniques. An evaluation conference is held each year with an independent panel of experts from non-participating institutions in order to correct deficiencies and to optimize utilization of the facility. To date coordinators at participant schools agree that spectroscopy and chromatography can be taught early or late in the curriculum without serious consequences to the student. A cost analysis for a large and small project similar to this.

project is included.

It thus appears that schools can add use of spectroscopic instruments and gas-liquid chromatography at about one-fourth the usual cost spread over a ten to fifteen year period by cooperating in this way.

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* Based on previous oral papers: Poster session paper 22, "Fourth Biennial Conference on Chemical Education", Madison, Wisconsin, August, 1976; Abstract 71, 172nd National Meeting, American Chemical Society, Chemical Education Division, San Francisco, Ca., August, 1977.

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THE PROBLEM That May Also be Your Problem

Many Departments of Chemistry stand essentially alone. Their teaching duties are carried out without significant interaction with neighboring Departments of Chemistry. Yet often within one day's driving time[1] several other departments will be functioning in much the same way. This paper will stress one of no doubt many ways near departments can cooperate for their mutual benefit.

Consider undergraduate laboratory instruction. In the past fifteen years major changes have occurred. Incorporation of experiments which involve instrumentation has increased to the point where graduates of many schools are expected to be proficient in obtaining and interpreting atomic absorption, infrared, ultraviolet-visible, nuclear magnetic resonance, and mass spectra and various kinds of chromatograms. Evidence for this trend can be seen in popular textbooks which incorporate chapters on spectroscopy and chromatography and new laboratory manuals which stress repeated use of these techniques.

Unfortunately these instruments are costly. A flame-ionization gas-liquid chromatograph and the five spectrometers listed above average over $50,000 at today's prices, and inflation continually increases this figure. Although some schools with better financial resources and/or a graduate program often have already purchased part or all of these instruments and others have made a modest beginning by purchasing a few of the less expensive instruments, many smaller colleges and universities are without sufficient funds to purchase all of these instruments. These latter schools now find themselves

with outdated or incomplete laboratory programs.

The problem of outright purchase of these needed instruments is three-fold. First, the high price of one instrument may be more than double or triple the entire annual budget of small departments. Often sufficient matching funds are unavailable so that these schools cannot take advantage of National Science Foundation programs to provide these instruments at reduced cost. Second, even when funds become available the number of students using a particular instrument and the fraction of the year it is used makes it doubly difficult for a Chemistry Department to justify the cost to an administrator. For example, an instrument may be utilized once each semester. Expenditure of ten or twenty thousand dollars is a sufficiently significant fraction of the total budget of a small school to cause reluctance to invest such a sum to teach, say, two seniors for 2 to 4 weeks. Third, these schools usually lack manpower with the time and electronic expertise to properly service these instruments. Consequently, instrument failure results in long time periods in which the instrument cannot be utilized while funds for repair are secured, and then these funds are used to pay expensive repairmen from the factory. Clearly these needed, but costly instruments present pressing problems to many.

SOLUTIONS That You May Have Tried

Schools without these instruments have largely adopted an approach to teaching these techniques which consists of lectures accompanied by pictures and diagrams on the methods, followed by assignment of spectra problems as homework. Staff members of larger schools often travel to the smaller schools and augment such lectures with seminars on the techniques. Occasionally instructors will bring some seniors to the larger schools for a demonstration of the use of the actual instrument. If a senior research project

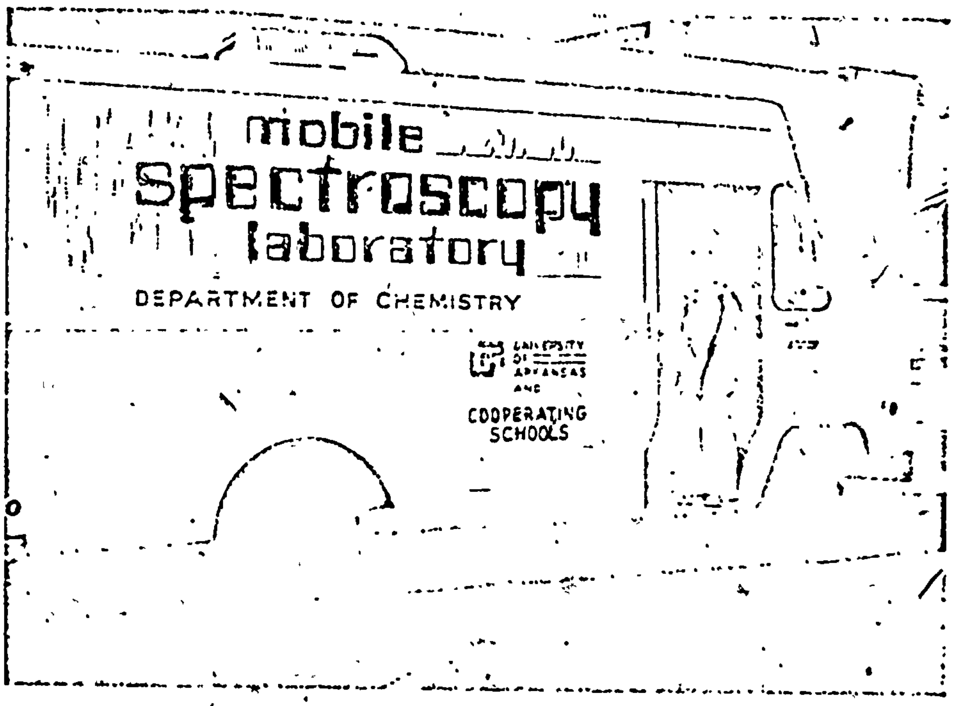
mobile
spectroscopy
laboratory
DEPARTMENT OF CHEMISTRY
COOPERATING
SCHOOLS

Figure 1

develops to the point of great need, service spectra can be obtained either from an obliging neighboring larger school with the instruments or by commercial laboratories offering this service. None of these devices approach in any way the valuable learning experience to be had in actual "hands on" use by the student of the instruments.

Recently several nearby schools brought their seniors to this laboratory to use our instruments to do a set of standard experiments during a Friday afternoon-night, Saturday morning session when our students were not utilizing the instruments heavily. Since their students had attended pre-arrival lectures, data gathering was quickly begun. Careful detailed analysis of the data and summary lectures were reserved until later. This entire experience seemed to indicate that pre-lecturing, then relatively short intense data gathering periods, followed by later detailed analysis can be <u>very useful</u> in teaching these instrumental techniques. In fact if the instruments are brought to the students (rather than the reverse), a way was envisaged to purchase one set of instruments and service a number of near schools.

THE PROPOSED SOLUTION <u>That You May Want to Try</u>

A cooperative mobile spectroscopy laboratory (Figure 1) circulating among thirteen nearby schools was proposed as a way to provide direct access to these instruments by the students. In this way a step van truck was to be utilized as the laboratory and would contain 60 MHz nuclear magnetic resonance, grating infrared, ultraviolet-visible, atomic absorption, and mass spectrometers and a flame ionization gas-liquid chromatograph. The mobile laboratory would stop one to two weeks at a school where the students would utilize the instruments to do locally determined experiments as part of their laboratory experience under the supervision of their regular on campus instructors. This paper describes implementation of this plan.

PLANNING-Ways of Solving Anticipated Problems That May Help You If You Try This Experiment

Anticipated problems were divided into two groups: (1) Problems on campus involving utilization of the truck and its instruments, and (2) General problems concerning the operation and maintain of the laboratory as a whole. For example spectroscopy and chromatography are subjects taught at set times in particular courses on each campus. The mobile laboratory can be physically present at only one or two times per year. Thus, alteration of the curriculum is often necessary if efficient utilization of the mobile-laboratory is to occur. Happily the schools involved in this project agree that spectroscopy and chromatography can be taught at almost any time in a given course, say organic chemistry, without serious problems. (Obviously, there is an ideal time for teaching any subject. However, this project does not claim to provide the ideal situation, only one in which the gains greatly outweigh the losses.) Thus lecturing on a given technique before the truck arrives followed by a relatively short period of intense data gathering when the mobile laboratory is present, and then data analysis after the laboratory has been moved to another campus was forseen as the new teaching experiment. After one and one-half years of testing there is unanimous agreement that this technique works!

The on campus coordinator for each school had to develop methods of utilization of the laboratory on the home campus which maximized students/instrument/time period. Unfortunately, a department made up of only one person may not be able to use all six of the instruments of the laboratory during a one week visit. Further, some of the schools own one or more instruments of the same type as those found on the truck and thus would not need to use one of the truck instruments. This situation was handled by packaging as many of the instruments as possible (four of six) in a way that allows them to be moved

and operated independently of the truck. Thus the infrared, ultraviolet-visible, and atomic absorption spectrometers, and the gas-liquid chromatograph were placed in removable drawers with handles (Figure 2) and can be routinely placed in a regular laboratory for use. In this way any instrument which will not be used during the visit of the truck-laboratory on a particular campus either due to time limitations or because a duplicate instrument exists, can be taken to another nearby school for use there. This practice which allows four instruments to be circulated independently of the truck allows the instruments to be used a higher percentage of the time. A given school does not have to utilize each of the six instruments during one week or then lose all opportunity to use them.

A minor point of concern in a project of this kind has to do with the nature of the cooperation involved. Occasionally a larger school will teach chemistry topics in a different order or even in different courses. Danger exists in a project of this kind that the larger school will dominate the smaller schools and force unwanted changes. <u>This is not the case in this project</u>. A guiding principle from the beginning has been that each school is completely free to use or not use any instrument and to employ experiments at any level of sophistication chosen in any class desired. In short, the larger school provides a laboratory as a service while the smaller schools are completely free to chart their own program and to pick and choose which instruments and experiments will be used.

Whether instruments are stationary or mobile, concern always exists as to how to keep the instruments operating. In fact instruments mounted in or carried by a truck might require much more attention. This problem was attacked in several ways. First, efforts were expanded to increase the technical competance of the on campus coordinators concerning the actual instru-

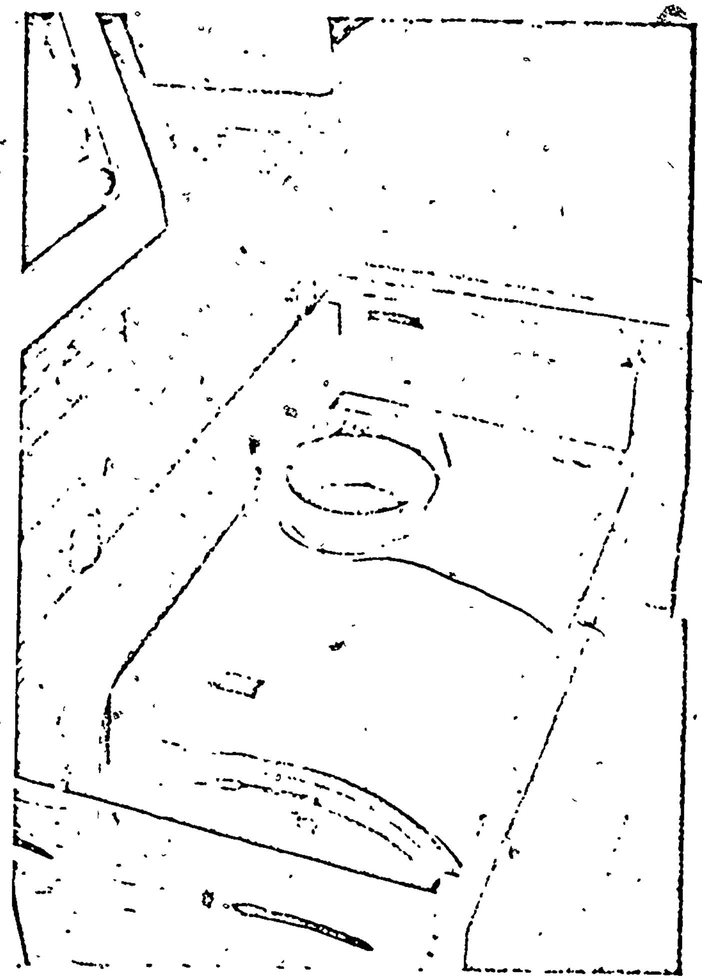

Figure 2

ments to be used with the truck. A brief survey of local instrumental problems has shown that 70-80% of these are essentially trivial: the student user has insufficient expertise, a switch or button has been improperly used, a fuse has failed, the sample is misaligned. To amend these faults and others, a six weeks workshop for the on campus coordinators was conducted in the summer prior to preparation of the laboratory. Not only was proper use and routine maintenance taught, but basic troubleshooting as well. After the covers of the instruments were removed, key voltage measurements were made and used to show how the source of malfunctions can be traced and localized. In this way the on campus coordinators possess a much broader knowledge of these instruments and how they function than is usually found in staff of Chemistry Departments. This knowledge often inables these coordinators to quickly repair a broken instrument. This preliminary training given to the coordinators of the participating schools is probably a major factor in the success of this cooperative experiment to date.

Second, two kinds of backup personnel are available to correct instrument problems. The University of Arkansas Department of Chemistry electronics expert is available at any time for telephone consultation by staff members of the participant schools. If such does not solve the problem, a graduate assistant is available to travel to the site and repair the broken instrument. If both of these methods fail, factory personnel can be brought in as a last resort.

The physical construction of the laboratory was viewed as a critical problem. For example previous experience has shown that a 60 MHz nuclear magnetic resonance spectrometer must be maintained at a relatively constant temperature. No school will wish to spend several of its five available school days waiting for a nmr to equilibrate! To solve this problem the truck was equipped with an air conditioner-heater and was heavily insulated

on all sides, top, and bottom with four inches of foam. A gasoline motor driven generator with 110 volt-40 amp output provides power to the air conditioner-heater during travel. An extension cord from commercial mains supplies the truck when it is parked. Without these precautions the nmr would often be unusable due to local temperature fluctuations that would cause significant variation of the magnetic field. Since the decoupler on the nmr has been functioning in Kansas during the winter and in Arkansas in the summer, temperature control is deemed satisfactory. Due to the heavy weight of the magnet and this necessary temperature control the nmr is permanently mounted in the mobile laboratory. (Figure 3)

Previous experience with mass spectrometers suggests that such a vacuum system is best maintained constantly. Since the mobile laboratory is always supplied with 110 volt power, either from commercial mains or from its own generator, the vacuum pump runs continually. For this reason the mass spectrometer is the other instrument that is permanently installed in the mobile laboratory (Figure 4) and is not transported into the regular laboratories for use there.

Two other problems surfaced during construction of the laboratory. First the nmr magnet was so heavy that thought was given as to what would happen to the magnet (and the driver!) should the truck strike a solid object when traveling at 55 m.p.h. The magnet was then chained to the floor so as to deter a flying magnet should some accident occur. Second, when the nmr was installed an approximately two cycle per second sine wave was noted on the recorder. Ultimately, this sine wave was traced to gentle, long term rocking of the truck on its springs and disappeared when the truck chassis was jacked up and placed solidly on jack stands.

Five times during the first semester of truck use the filament in the mass spectrometer failed. Probably these failures were due to large, repeated injections of heavily halogenated hydrocarbons such as carbon tetrachloride or

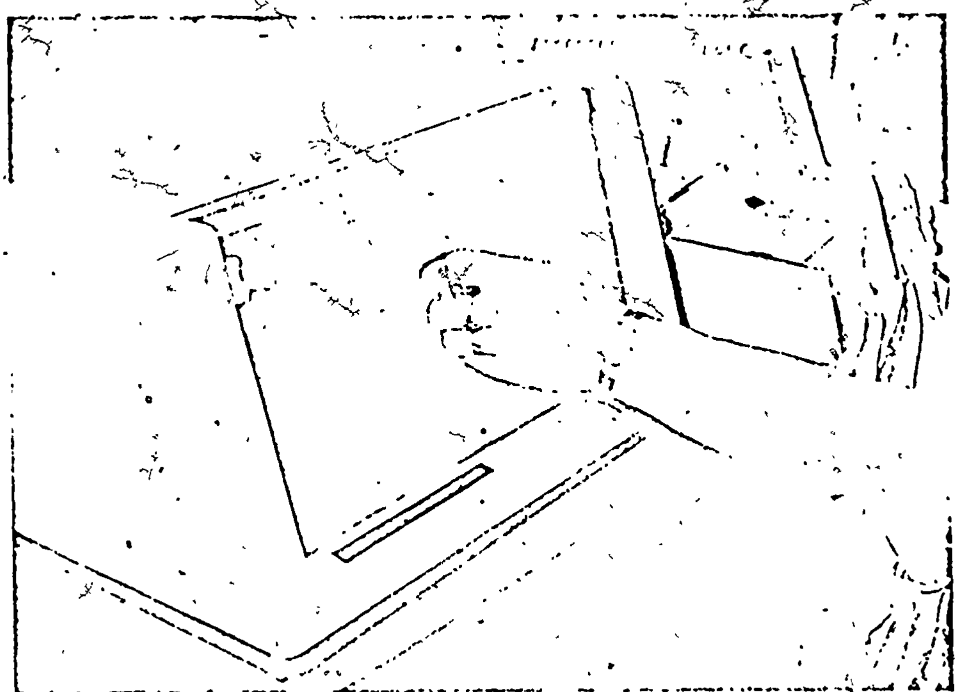

Figure 3

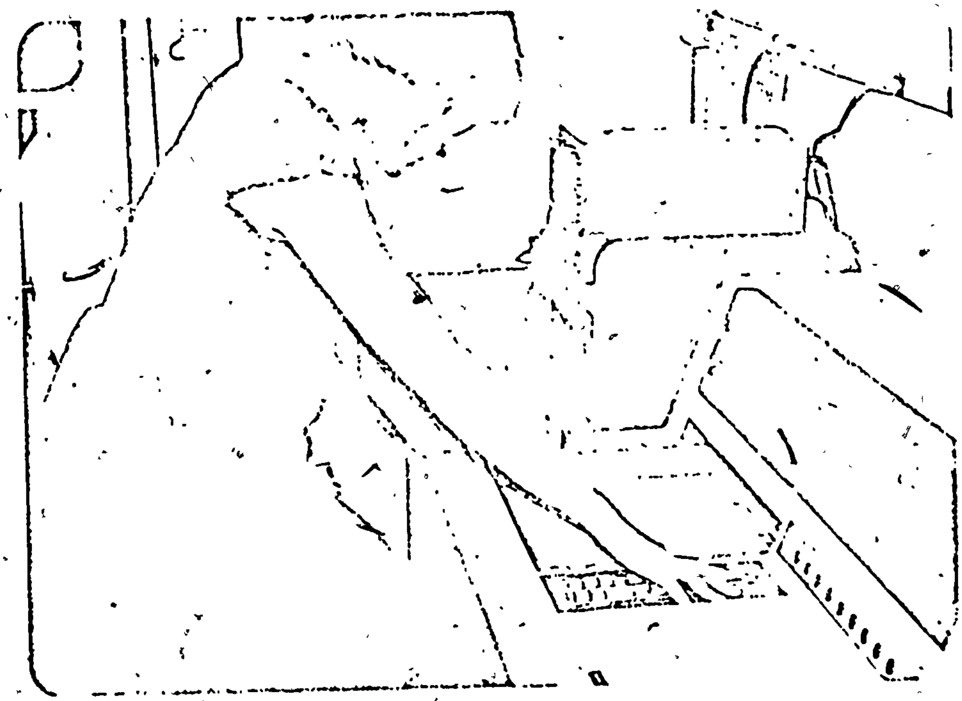

Figure 4

chloroform in order to illustrate isotope abundance ratios, or to inadvertent misuse by first time users. (At first vibration due to travel was suspected to be the cause of filament failure. However two long trips totaling over four thousand miles did not ruin a filament. Travel vibration has thus been dismissed as a cause of filament failure.) Since a filament is expensive and often is obtained slowly from the supplier, some alternative solution was desired. The required wire for the filament could be readily purchased[2] and with a little practice arc-welded in the place of the old broken filament. In addition to providing a relatively rapid method of repairing a broken filament, this procedure dropped the cost of filament replacement from over $60 to less than $1, a satisfactory price even if one filament fails each week.

COST ANALYSIS-Slanted Toward Those Who May Want to Try This Experiment

Many may feel that this experiment could be repeated elsewhere with great advantage, if financial aspects could be arranged. Therefore this section of this paper will be devoted to analysis of possible costs and possible sources of support. However, the reader is cautioned that this analysis is based on approximate figures[3] and will vary with locality and specific designs of projects. Further, inflation should be kept in mind.

A Shoestring Budget-The initial assumptions for the first budget are: (1) Only two instruments will be purchased, a 60 MHz nmr[4] and a small mass spectrometer. (2) Every effort will be made to cut costs.[5] (3) Ten schools are cooperating in this venture.[6]

DIRECT COSTS

Spectrometers[7]	22,000
Truck[8]	10,000
Initial funds to build the laboratory[9]	32,000

YEARLY UPKEEP FOR THE ENTIRE PROJECT

Truck	150

Instruments[10]	150
Insurance	500
Amount set aside to replace the truck and instruments every ten years	3200
Total costs/year	4000

COST FOR ONE SCHOOL OF TEN/YEAR

One Share of Initial Costs	3200
One Share of Yearly Upkeep Costs	400

TOTAL COSTS TO ONE SCHOOL FOR TEN YEARS

Initial Cost	3200
Upkeep for ten years	4000
	7200

Thus for about one-third the purchase price of the two needed instruments a school can provide for itself access to these instruments for ten years and then have new state-of-the-art instruments for the next ten years <u>at no extra costs</u>. (Further, once the initial costs are met, yearly costs are only $400. If funds are not set aside year after year to replace worn-out instruments a time will come when they become useless.)

<u>A Larger Budget</u> - If the present project is duplicated the costs are higher.[11]

DIRECT COSTS

Spectrometers	40,000
Parts, other equipment	3,000
Truck	13,000
Initial fund to build laboratory	56,000

YEARLY UPKEEP FOR THE ENTIRE PROJECT

Truck	200
Instruments	150
Insurance	1092
Repair Trips	100
Amount Set Aside to replace truck every twelve years	4667
Total Costs/Year	6209

COST FOR ONE SCHOOL OF THIRTEEN/YEAR

One Share of Initial Costs	4308
One Share of Yearly Upkeep	478

TOTAL COSTS TO ONE SCHOOL FOR TWELVE YEARS

Initial Cost	4308
Upkeep for Twelve Years	5736
	10,044

Thus for about one-fourth the purchase price of the six instruments, a school can provide for its students access to these instruments. The same bonus features as above apply to this budget: After twelve years state-of-the-art instruments are had as replacements for the worn-out instruments. Repairs are included in the costs.

Sources of funds for projects such as this one are not many. For example the National Science Foundation is committed to new experiments. Thus NSF is unlikely to approve funding for a similar project unless there are significant new aspects. Since in this project $1 functions for $3 or $4 spent in the usual way, private foundations might be favorably impressed and provide funding. Local state educational sources might also be interested, at least in helping a group get started, especially since funding for one time only would be involved. Finally a particular school might sell an existing instrument or donate an existing instrument as part of the initial investment.

EVALUATION: Is This Experiment a Success?

Only one and one-half years of use of the truck-laboratory is not enough time to really ascertain whether or not this project is a success. However at this point a positive attitude exists based on the following analysis.

Value Added: By being a part of this project the students of a given school can now do several experiments on instruments which could not be done otherwise. In this way the programs of these schools have been enriched.

Cost-effectiveness: As the project now stands the least expensive method of providing access to these instruments is via this mobile spectroscopy

laboratory arrangement. In fact, as is shown above in the Cost Analysis section, even if every dollar had to be provided apart from grant support the truck-laboratory would still be the best buy and thus provide more instruments per dollar spent.

Marketplace Adaptability: There are more than 300 small schools in the United States alone that could conceivably benefit from similar projects. Even if a school now has most of the needed expensive instruments, the passage of time will make these obsolete and new or updated versions will be desired. This technique of cooperating together is still the most cost-effective, widely adaptable method of providing such instrumentation.

Attitude Changes: Chemists are no different from others in trying to evaluate intangibles, such as attitude changes. The combined opinion of all concerned with this project is that attitudes have changed. Some of the loneliness of semi-isolation is gone. Some of the feeling that "Others have better equipment," is gone. Some of the feeling that "We are a bit behind," is dissipating. Students are surely excited, but this is to be expected when new instruments and new capabilities are presented. One school has re-installed a bachelor degree program in chemistry partly as a result of this truck project. From all that can be observed, attitudes have changed in a positive way.

The final test of this project will come during the next year when the participants begin to fund the project from their own budgets. If the truck-laboratory is really valuable these schools will continue to be a part of the project. If not, the project will die from lack of financial support, as it should.

WORKING TOGETHER: An aspect of this project that should not die.

One of the less emphasized or even expected aspects of this project has to do with cooperation. Often there exists reluctance to interact

closely with neighboring chemistry departments. As a part of this project coordinators from 13 schools in 2 states have been forced to work closely with each other, to compromise and propose, to give and to take, and often to learn that others have similar problems or know of unique solutions to similar problems. It has been unanimously agreed that great benefits and lasting friendships have occurred from such cooperation.

As has been emphasized above a key to the success of this venture has been the attitude prevailing from the beginning that this project is not one of coercion but cooperation. Although the coordinating school is larger than any of the other schools, no effort has been put forth to cause any school to alter its program or presentation except along voluntary lines. Rather the larger school remains intent on providing a service which is adaptable enough to benefit each smaller school. In this way a smaller school as it charts its own destiny can pick and choose which part of the service, if any, is incorporated into its own self-determined program.

Finally, a comment should be made about the role of larger schools in future experiments of this kind. Although several small schools can combine together and successfully manage a project of this kind, a larger school will have many resources which can be provided at almost no cost or inconvenience that will make the project much easier to carry out. In this way a combine of one larger school and a group of neighboring smaller schools will invariably provide working relationships that are highly valuable and harder to build otherwise.

Acknowledgement

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Notes

1. Although schools at the extremes are 800 miles apart, a number of schools in this project are less than 50 miles apart.
2. A. D. Mackey inc., 198 Broadway, New York, N.Y., 10038.
3. Estimates are from actual costs in this project, plus a small amount for inflation.
4. Thirty-MHz instruments are available, but are deemed not as useful in teaching.
5. For example this budget does not contain funds for payment of factory personnel to repair instruments. The assumption is made that a nearby larger school will donate a few days per year of time by personnel from their electronics shop.
6. Ten is a completely arbitrary choice, but may in fact represent the number of schools that can conveniently use the facility.
7. This amount can vary widely as a function of the number of extra attachments purchased.
8. This figure does not include a generator to provide power during travel. This practice would require that three days be provided for the nmr to come to equilibrium. For a project with fewer schools and larger time periods at each stopping point, such may not be a problem.
9. Note that salaries of chemistry personnel involved with the project are not included. Thus the time involved must be donated or covered in some other way.
10. This amount will surely vary with the locality.
11. These amounts are from this project's budget.

Captions for Figures

Figure 1: The Mobile Spectroscopy Laboratory is housed in a 12' x 8' x 8' Step Van truck.

Figure 2: The atomic absorption spectrometer and three other spectrometers are transported in padded drawers with handles cut into the ends. After the spectrometers are moved into the regular laboratory, students can use them without being crowded.

Figure 3: The nuclear magnetic resonance spectrometer has a heavy magnet and requires a constant temperature. For these reasons it is permanently mounted in the truck and used there.

Figure 4: The mass spectrometer requires a high vacuum which is maintained constantly. For this reason it is permanently mounted in the truck and used there.

All pictures for the figures were taken by Ron Miller.

Description of Extra Pictures

1. The atomic absorption spectrometer is usually set up in a hood for use by students in the regular laboratory of the participating school.
2. A group picture of the project director and the on campus coordinators.
3. The nmr is tuned by the students by using an oscilloscope which is permanently mounted in the truck.

4-6. A picture of the mobile laboratory which shows the names of the participating colleges and universities.

7. Students vary parameters and observe the effects on the nmr spectra as part of their learning process.
8. Cooperation brings many benefits. One of the benefits is a mutual exchange of ideas. Here W. Johnson (Tabor College) makes a point to Y.C. Chang (Kansas Wesleyan University) T. Lehman (Bethel College), R. Zerger (McPherson College) and J. Holliday (John Brown University).
9. The mobile laboratory is usually situated in a parking lot just outside the Chemistry Building at a particular school. An extension cord brings commercial electrical power to the truck.

10-14. Each year an independent panel reviews progress and offers constructive critism. Panel members are: Professors K. Takemura (Creighton University) and W.T. Lippincott (University of Arizona) and Dean Calvin Vanderwerf (University of Florida).

Pictures 1,3,7,9 were taken by Ron Miller.
Pictures 2,4-6,8,10-14 were taken by James Wisman.

KINDS OF CHEMISTRY THAT ARE POSSIBLE IN A MOBILE SPECTROSCOPY LABORATORY

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University of Arkansas, Fayetteville, Arkansas 72701

and

Participating Schools[1]

1. Participating Schools (with on campus coordinator initials in brackets) are: Arkansas College (R. M. B. and V. P. K.), Batesville, AR; Bethany College (M. L. M.), Lindsborg, KS, Bethel College (T. A. L.), N. Newton, KS, College of the Ozarks (S. M. C.), Clarksville, AR; Harding College (E. W. W.), Searcy, AR; John Brown University (J. R. H.), Siloam Springs, AR; Kansas Wesleyan University, (Y. C. C.), Salina, KS; McPherson College (R. P. Z.), McPherson, KS; Ouachita Baptist University (W. W. E.), Arkadelphia, AR; Sterling College (D. D. P.), Sterling, KS; Tabor College (W. J. J. and L. N.), Hillsboro, KS; University of Arkansas at Monticello (W. E. G.), Monticello, AR; University of Arkansas at Pine Bluff (W. M. W.), Pine Bluff, AR.

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Abstract 73, 173rd National Meeting, American Chemical Society, Chemical Education Division, New Orleans, La., March, 1977.

Previously[2] a mobile spectroscopy laboratory has been described as a means by which smaller schools may cooperate so as to provide for their students a laboratory experience with more expensive spectroscopic and chromatographic instruments. In order to stimulate others to try this cooperative venture the types of chemistry experiments which are possible and which have been actually used will be described in this paper.

The first point to be stressed is that exotic and/or odd experiments are not necessary for use in the truck laboratory. The usual experiments are easily done. For example the major use of these instruments has been to solve "unknowns" at all levels of instruction. Such work requires the student to learn to operate the instrument correctly, obtain the data, and then interpret the data--the usual use of instruments by chemists. This practice is especially apparant in second semester sophomore organic courses where the student uses ir, nmr, and mass spectroscopy to deduce the structure of simple "unknowns". Demonstrations of the use of these instruments are often provided for non-science majors and visiting high school students. The usual detailed instructions on how to use the instruments are reserved for science majors. (These are the students which will use the instruments in semesters to come and often are very helpful in setting up the laboratory when it arrives. Often these same students can be utilized to give demonstrations and teach new students how to use the instruments.)

Freshman students in general chemistry can easily be taught to use the atomic absorption spectrometer. Analysis of tap water from various sources illustrates wide variation in concentrations of heavy metals

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2. Previous paper, This Journal.

such as lead, zinc, and copper. Analysis of calcium and magnesium concentrations show the "hardness" of water and that "water softeners" really work. Two other experiments that became quick favorites involve analyses of heavy metals in different cigarette brands and analyses of the concentration of sodium and potassium in urine and blood. Students supply samples in each case.

Freshman students also have utilized the ultraviolet-visible spectrometer to monitor air quality. Air is pumped through solutions containing trapping reagents for sulfur dioxide, nitrogen dioxide, or ozone. The increase in ultraviolet or visible absorption can be easily related to concentration. Heavy metals such as iron or manganese in samples taken from rivers, lakes, and streams can also be extracted by trapping reagents and analyzed in the same way. Nitrate and phosphate concentrations have also been checked using this method.

A popular demonstration for freshmen has been the determination of $^{32}S/^{34}S$ in nature by use of the mass spectrometer. Carbon disulfide is often the sample which is used. If possible an upper classman carries out the actual demonstration.

In addition to the "unknowns" which are solved by sophomores as mentioned above, the organic laboratory utilizes the flame-ionization gas-liquid chromatograph to strengthen the first semester. For example a hydrocarbon, say 2-methylbutane, is halogenated and the products worked up, and then stored until the truck arrives. Then percentages of each of the products can be determined. The results show that various hydrogen types are substituted at different rates in free radical halogenation. Analyses of fractions from distillation of a mixture through a Vigreaux or similar column show efficiencies of distillation. The most popular experiment

involves analyses of "regular grade" gasoline from name brand versus discount service stations. Since both stations buy from the same refinery, the analyses are virtually identical.

Senior research projects connected to use of the truck-laboratory are stimulating to involved faculty members. Several types of projects previously unfeasible can be accomplished. Samples are prepared. Experiments are run. Then when the truck arrives feverish activity occurs so that all the samples can be analyzed. (Students have been known to willingly operate the instruments around the clock!) Even students not yet ready to do a senior level research project are often interested in environmental pollution projects in connection with say, an analytical course. Again gathering samples before the truck arrives and then diligently obtaining data while the truck is present is standard practice.

In summary the truck-laboratory is used in the same kind of chemistry experiments as if the instruments were permanently located.

Acknowledgement:

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